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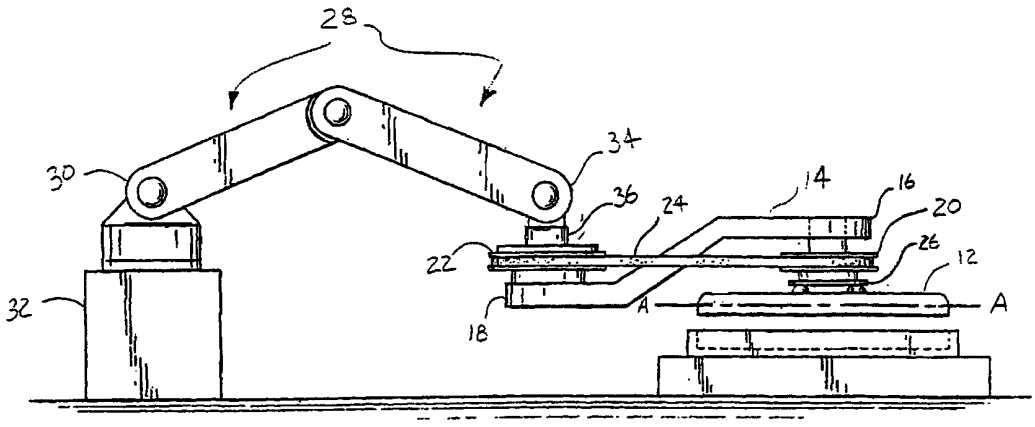
(54) Title: CONSTANT ORIENTATION ROBOT ARM ASSEMBLY




(57) Abstract: A robot arm assembly (10) and method for moving a workpiece (12) while maintaining a constant workpiece (12) orientation includes a first link (14) with a first pulley (20) rotatably supported at a first end (16) of the first link (14). A second pulley (22) is disposed at a second end (18) of the first link (14). A coupling (24) prevents relative rotation between the first (20) and second pulleys (22). The first (20) and second pulleys (22) have different radii that establish a ratio of rotation. Fixedly attached to the first pulley (20) is a tool (26) adapted to releasably grip the workpiece (12). A second link (28) is mounted to a support at a first end (30) and rotatably connected to the first link (14) at a second end (34). The coupling of the pulleys (20, 22) limits rotation of the tool (26) and workpiece (12) relative to a reference plane A as the second link (28) rotates relative to the support and the first link (14) rotates relative to the second link (28). The rotation of the first link (14), relative to the second link (28) are part of a robot operating software program for moving the workpiece (12).

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# CONSTANT ORIENTATION ROBOT ARM ASSEMBLY

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

The subject invention relates to a robot arm assembly utilized to transfer a workpiece.

### 2.Description of the Prior Art

A workpiece transfer mechanism is utilized to move a workpiece between workstations. One example of how a workpiece transfer mechanism is utilized is an automotive panel stamping line. In an automotive panel stamping line the panel is moved through a line of stamping presses to progressively stamp and form a desired panel shape. For economic reasons, minimizing cycle time is of great importance. Traditional methods require the panel to be removed from a first press in a straight-line path and once clear of the first press, rotated 180 degrees before being placed into a second press. The completed path is inefficient. This inefficiency is compounded when larger and heavier panels are to be moved. A straight path where the panel is not rotated provides for an optimal cycle time. Rotation of the workpiece imparts a significant inertial load on the transfer mechanism, causing the need for a more substantial and costly structure.

The U.S. patent 3,010,587 to Hollinger discloses a workpiece transfer mechanism adapted to move a workpiece between stamping presses in a straight path. The work piece transfer mechanism of the Hollinger '587 patent includes a stationary sprocket wheel adjustably secured to the upper face of a support plate. A shaft from a power drive means extends vertically upward above the sprocket wheel. Fixedly mounted on the shaft is a main radial arm. A second vertical shaft is rotatably mounted at a second end of the main radial arm. A rotary sprocket wheel is fixed on the lower end of the second vertical shaft. The rotary sprocket wheel is coupled to the stationary sprocket wheel by a chain. A first end of an auxiliary radial arm is fixedly mounted to

the rotary sprocket wheel. A gripping means for releasably gripping a workpiece is disposed at a second end of the auxiliary radial arm.

Straight-line movement of a workpiece is accomplished by the main radial arm and the auxiliary radial arm having equal effective lengths and by maintaining a two to one ratio between the radii of the stationary sprocket wheel and the rotary sprocket wheel. In operation, the power drive means will rotate the main radial arm in a counterclockwise direction, and because of the coupling between the stationary sprocket wheel and the rotary sprocket wheel, the auxiliary radial arm will rotate in a clockwise direction.

The Hollinger transfer mechanism moves the workpiece in a straight-line path, but rotates the workpiece 180 degrees relative to a support. The rotation of the workpiece or panel creates significant inertial loading, thereby limiting the size of a workpiece that can be transferred with a given structure. In addition, the rotation of the part prevents attaining the optimal cycle time. Furthermore, the Hollinger transfer mechanism is not programmable to allow adaptation to variations in pitch or height between presses nor does the Hollinger transfer mechanism allow for the frequently encountered need to impart slight pitch and roll motions to aid the release of a workpiece or panel as is possible with the use of robots.

## SUMMARY OF THE INVENTION AND ADVANTAGES

The subject invention relates to a robot arm assembly utilized to move a workpiece between workstations while maintaining the orientation of the workpiece relative to a reference plane. The robot arm assembly comprises a first link having a first and a second end and a tool mounted to the first end of the first link and a second link having a first end rotatably mounted on a support and a second end rotatably connected to the first link. The robot arm assembly is characterized by a coupling between the second link and the tool for limiting rotation of the tool relative to the

reference plane as the second link rotates relative to the support and the first link rotates relative to the second link.

The subject invention includes the method of moving a workpiece comprising the steps of rotating the second link about the support, rotating the first link relative to the second link, and rotating the tool relative to the first link in a predetermined ratio to the rotation of the second link relative to the first link. Further, the steps of rotating the second link about a support, rotating the first link relative to the second link, and adjusting an angle of rotation of the workpiece are accomplished as part of a robot operating software program for moving the workpiece.

The robot arm assembly maintains workpiece orientation during transfer between workstations without requiring a 180-degree rotation of the workpiece. Maintaining the workpiece orientation provides for optimal cycle time. In addition, by maintaining the workpiece orientation, inertial loading on the robot arm assembly caused by rotation of the workpiece is minimized.

## BRIEF DESCRIPTION OF THE DRAWINGS

Other advantages of the present invention will be readily appreciated, as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

Figure 1 is a side view of a robot arm assembly;

Figure 2 is a top view of the robot arm assembly;

Figure 3 is a process view of the steps required to move a workpiece between workstations using the subject robot arm assembly; and

Figure 4 is a top view of the robot arm assembly illustrating the angular relationships between components of the robot arm.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the Figures, wherein like numerals indicate like or corresponding parts throughout the several views. A robot arm assembly **10** for moving a workpiece **12** while maintaining a constant workpiece **12** orientation is shown in Figure 1. The robot arm assembly **10** includes a first link **14** having a first end **16** and a second end **18**. A tool **26** is rotatably mounted to the first end **16** of the first link **14**. A coupling **24** is provided to limit the rotation of the tool **26** relative to a reference plane **A**. The coupling **24** is comprised of a first pulley **20** rotatably supported at a first end **16** of a first link **14**, and a second pulley **22** disposed at a second end **18** of the first link **14.** The pulley **20** and the tool **26** are fixedly coupled.

The robot arm assembly **10** is controlled by a control system that drives the links **28**, **14** of the robot arm assembly **10** in accordance with a robot operating software program to attain desired robot arm assembly **10** motions and tool **26** manipulation.

The pulleys **20, 22** shown in Figure 1 are disk shaped with a circumference having a grooved rim (not numbered), and coupled by a belt **24** trained around the pulleys **20,22** and disposed within the grooved rim. It should be appreciated that the pulley **20,22** and belt combination is only one of many possible coupling configurations. Examples of other configurations might include a sprocket and chain configuration, a lever configuration, or a system of gears. Further, any other coupling means known in the art may be substituted for the preferred pulley **20,22** and belt **24** configuration.

The robot arm assembly **10** is characterized by a second link **28** having a first end **30** mounted to a support **32** and a second end **34** rotatably connected to the first link **14,** and the coupling **24** limiting rotation of the tool **26** relative to a reference plane **A** as the second link **28** rotates relative to the support **32** and the first link **14** rotates relative to the second link **28**. The second link **28** shown in Figure 1 comprises two links attached at a central pivot. The central pivot allows the overall distance between the first and second ends of the second link **28** to change during movement of the workpiece **12**. Figure 3 illustrates how this configuration allows the robot arm

assembly **10** to extend into restricted areas while maintaining the orientation of the workpiece **12** substantially unchanged relative to the reference plane A.

Referring now to Figure 2, the first and second pulleys **20,22** have different radii to establish a ratio of rotation. The ratio between the radius of the first pulley **20** and the radius of the second pulley **22** in the first embodiment is two to one. It should be understood that the ratio between the radius of the first pulley **20** and the radius of the second pulley **22** is dependent on the application and can be adjusted accordingly to accommodate multiple robot arm assembly **10** configurations. Referring now to Figure 4, the ratio between the pulleys may be determined by using the following equations:

$$\Delta\theta3 = \Delta\theta2(1- (R1/R3)) +(\Delta\theta1) \qquad \text{Equation 1}$$

Where $\Delta\theta1$ = Angle of rotation of the second link **28** about the support **32**.

$\Delta\theta2$ = Angle of rotation of the first link **14** relative to the second link **28**.

$\Delta\theta3$ = Angle of rotation of the workpiece **12** relative to the support **32**.

R1 = Radius of the second pulley **22**.

R3 = Radius of the first pulley **20**.

Further, when it is desired to maintain the workpiece **12** orientation, i.e. $\Delta\theta3=0$, then Equation 1 becomes:

$$R1/R3 = (\Delta\theta2 + \Delta\theta1)/(\Delta\theta2) \qquad \text{Equation 2}$$

or $$\Delta\theta1/\Delta\theta2= ((R1/R3)-1) \qquad \text{Equation 3}$$

The use of equations 1, 2 and 3 to determine a ratio of rotation allows for the accommodation of multiple robot arm configurations. Different robot arm configurations can be obtained by varying lengths of the first **14** and second links **28**. Further, the second link **28** may be comprised of a plurality of serially and rotationally connected links. The plurality of serial and rotationally connected links would provide for multiple robot arm assembly **10** configurations to accommodate different applications. In practice, the ratio between the first pulley **20** and second pulley **22** is usually sized such that the angle of rotation of the workpiece $\Delta\theta3$ with respect to the support **32** is zero at least at one location within the operating space of the robot arm

assembly **10**. During operation, the robot arm assembly **10** can be programmed to vary the rotation of the workpiece **12** according to Equation 1 to control rotation of the workpiece **12** and minimize cycle time. A motor **36** mounted on the pulley **22** and the second link **28** and attached to the first link **14** facilitates rotation of the first link **14** relative to the second link **28** and the pulley **22**. It should be understood that other means known in the art may be employed to rotate the first link **14** relative to the second link **28**. In a typical robot arm assembly **10** the motor **36** is disposed within a wrist housing and drives a robot flange to which the first link **14** may be attached. The pulley **22** is fixedly attached to the wrist housing.

The subject invention includes methods of moving a workpiece **12** by the tool **26** rotatably mounted on the first end **16** of the first link **14** and moving the second link **28** that is pivotally connected to the second end **18** of the first link **14**. Referring to Figures 3 and 4, the method comprises the steps of rotating the second link **28** about the support **32**, rotating the first link **14** relative to the second link **28**, and rotating the tool **26** relative to the first link **14** in a predetermined ratio to the rotation of the second link **28** relative to the first link **14**. A marker **13**, detailed in Figure 4, disposed on the workpiece **12** follows the change of orientation of the workpiece **12** throughout the angle of rotation $\Delta\theta 3$.

Further included is the step of coupling the rotation of the second link **28** relative to the first link **14** with the rotation of the tool **26** relative to the first link **14**. By coupling the rotation of the tool **26** to the rotation of the first link **14** in the predetermined ratio, the tool **26** rotates in unison with the second link **28** as the second link **28** rotates relative to the first link **14**.

Another method of moving a workpiece with the robot arm assembly **10** comprises the steps of, providing a rotational coupling **24** such that the tool **26** and the second link **28** rotate relative to the support **32** with a predetermined ratio or rotation. Rotating the second link **28** around the support **32** by the angle $\Delta\theta 1$, rotating the first link **14** by the motor **36** such that a center of gravity of the workpiece **12** travels along

a predetermined path, and adjusting the angle of rotation $\Delta\theta 2$ of the first link **14** relative to the second link **28** such that a rotation of the workpiece $\Delta\theta 3$ is minimized. In addition, the steps of rotating the second link **28**, rotating the first link **14**, and adjusting the angle of rotation $\Delta\theta 2$ of the first link **14** relative to the second link **28** are part of a robot operating software program for moving the workpiece **12**.

The invention has been described in an illustrative manner, and it is to be understood that the terminology that has been used is intended to be in the nature of words of description rather than of limitation.

Obviously, many modifications and variations of the present invention are possible in light of the above teachings. The invention may be practiced otherwise than as specifically described within the scope of the appended claims, wherein that which is prior art is antecedent to the novelty set forth in the "characterized by" clause. The novelty is meant to be particularly and distinctly recited in the "characterized by" clause whereas the antecedent recitations merely set forth the old and well-known combination in which the invention resides. These antecedent recitations should be interpreted to cover any combination in which the inventive novelty has utility. In addition, the reference numerals are merely for convenience and are not to be in any way to be read as limiting.

# CLAIMS

What is claimed is:

1. A robot arm assembly **(10)** for moving a workpiece **(12)**, said robot arm assembly **(10)** comprising;

a first link **(14)** having a first end **(16)** and a second end **(18)**; and

a tool **(26)** mounted to said first end **(16)** of said first link **(14)**;

a second link **(28)** having a first end **(30)** mounted on a support **(32)** and a second end **(34)** rotatably connected to said first link **(14)**;

said robot arm assembly **(10)** characterized by a coupling **(24)** between said second link **(28)** and said tool **(26)**, said coupling **(24)** limiting rotation of said tool **(26)** relative to a reference plane **A** as said second link **(28)** rotates relative to said support **(32)** and said first link **(14)** rotates relative to said second link **(28)**.

2. An assembly as set forth in claim 1 further characterized by said coupling **(24)** comprising a first pulley **(20)** rotatably mounted to said first end **(16)** of said first link **(14)**; and a second pulley **(22)** disposed at said second end **(18)** of said first link **(14)** with said second pulley **(22)** fixedly attached to said second link **(28)**.

3. An assembly as set forth in claim 2 further characterized by said first pulley **(20)** and said second pulley **(22)** having different radii for establishing a predetermined ratio of rotation between said first pulley **(20)** and second pulley **(22)**.

4. An assembly as set forth in claim 2 further characterized by said pulleys **(20,22)** being disk shaped with a circumference, wherein said coupling **(24)** includes an endless belt **(24)** trained around said pulleys **(20,22).**

5. An assembly as set forth in claim 4 further characterized by said pulleys having a grooved rim with said endless belt disposed within said grooved rim.

6. An assembly as set forth in claim 3 further characterized by said ratio between said first pulley **(20)** and said second pulley **(22)** determined by an equation, wherein said equation is $\Delta\theta3 = \Delta\theta2(1-(R1/R3))+(\Delta\theta1)$;

where $\Delta\theta1$ = angle of rotation of said second link **(28)** about said support **(32)**;

$\Delta\theta2$ = angle of rotation of said first link **(14)** relative to said second link **(28)**;

$\Delta\theta3$ = angle of rotation of said workpiece **(12)** relative to said support **(32)**;

R1 = radius of said second pulley **(22)**; and

R3 = radius of said first pulley **(20)**.

7. An assembly as set forth in claim 3 further characterized by said ratio between said first pulley **(20)** and said second pulley **(22)** being two to one.

8. An assembly as set forth in claim 1 further characterized by said second link **(28)** comprises a plurality of serially and rotationally connected links.

9. An assembly as set forth in claim 1 further characterized by a motor **(36)** mounted on said second link **(28)** and attached to said first link **(14)** to facilitate rotation of said first link **(14)** relative to said second link **(28)**.

10. A method of moving a workpiece **(12)** by a robot arm assembly **(10)** having a tool **(26)** rotatably mounted on a first end **(16)** of a first link **(14)** by moving a second link **(28)** which is pivotally connected to a second end **(18)** of the first link **(14)**, said method comprising the steps of;

rotating the second link **(28)** about a support **(32)**;

rotating the first link **(14)** relative to the second link **(28)**; and

rotating the tool relative to the first link **(14)** in a predetermined ratio to the rotation of the second link **(28)** relative to the first link **(14)**.

11. A method as set forth in claim 10 further including coupling the rotation of the second link (**28**) relative to the first link (**14**) with the rotation of the tool (**26**) relative to the first link (**14**) to rotate the tool (**26**) in the predetermined ratio to the rotation of the second link (**28**) relative to the first link (**14**) to rotate the tool (**26**) in unison with the rotation of the second link (**28**) relative to the first link (**14**).

12. A method as set forth in claim 10 where the rotation of the tool (**26**) in the predetermined ratio is further defined by utilizing an equation, wherein said equation is $\Delta\theta3 = \Delta\theta2(1-(R1/R3))+\Delta\theta1$;

where $\Delta\theta1$ = angle of rotation of said second link (**28**) about said support (**32**);

$\Delta\theta2$ = angle of rotation of said first link (**14**) relative to said second link (**28**);

$\Delta\theta3$ = angle of rotation of said workpiece (**12**) relative to said support (**32**);

R1 = radius of said second pulley (**22**); and

R3 = radius of said first pulley (**20**).

13. A method as set forth in claim 10 further including rotating the tool (**26**) by a two to one ratio of rotation relative to the second link (**28**).

14. An assembly as set forth in claim 11 including rotating the first link (**14**) relative to the second link (**28**).

15. A method of moving a workpiece (**12**) by a robot arm assembly (**10**) comprising a support (**32**), a second link (**28**) having a motor (**36**) disposed at an end (**34**) of the second link (**28**), a first link (**14**) driven by the motor (**36**) and a tool (**26**) supporting the workpiece (**12**), said method comprising the steps of:

providing a rotational coupling (**24**) such that the tool (**26**) and the second link (**28**) rotate relative to the support (**32**) with a predetermined ratio of rotation;

rotating the second link (**28**) around the support (**32**) by an angle of rotation $\Delta\theta 1$;

rotating the first link (**14**) by the motor (**36**) such that a center of gravity of the workpiece (**12**) travels along a predetermined path; and

adjusting an angle of rotation $\Delta\theta 2$ of the first link (**14**) relative to the second link (**28**) such that an angle of rotation $\Delta\theta 3$ of the workpiece (**12**) is minimized;

where $\Delta\theta 1$ = angle of rotation of the second link (**28**) about the support (**32**);

$\Delta\theta 2$ = angle of rotation of the first link (**14**) relative to the second link (**28**); and

$\Delta\theta 3$ = angle of rotation of the workpiece (**12**) relative to the support (**32**).

16. The method of claim 15 wherein the steps of rotating the second link (**28**), rotating the first link (**14**), and adjusting the angle of rotation $\Delta\theta 2$ of the first link (**14**) relative to the second link (**28**) are part of a robot operating software program for moving the workpiece (**12**).

FIG - 1

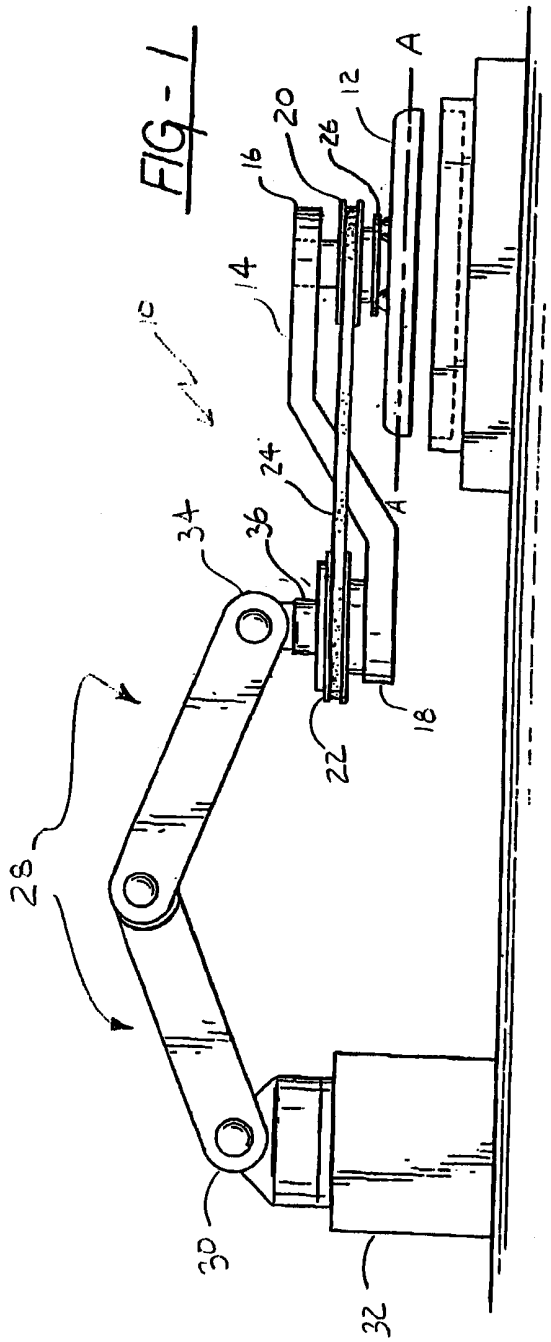
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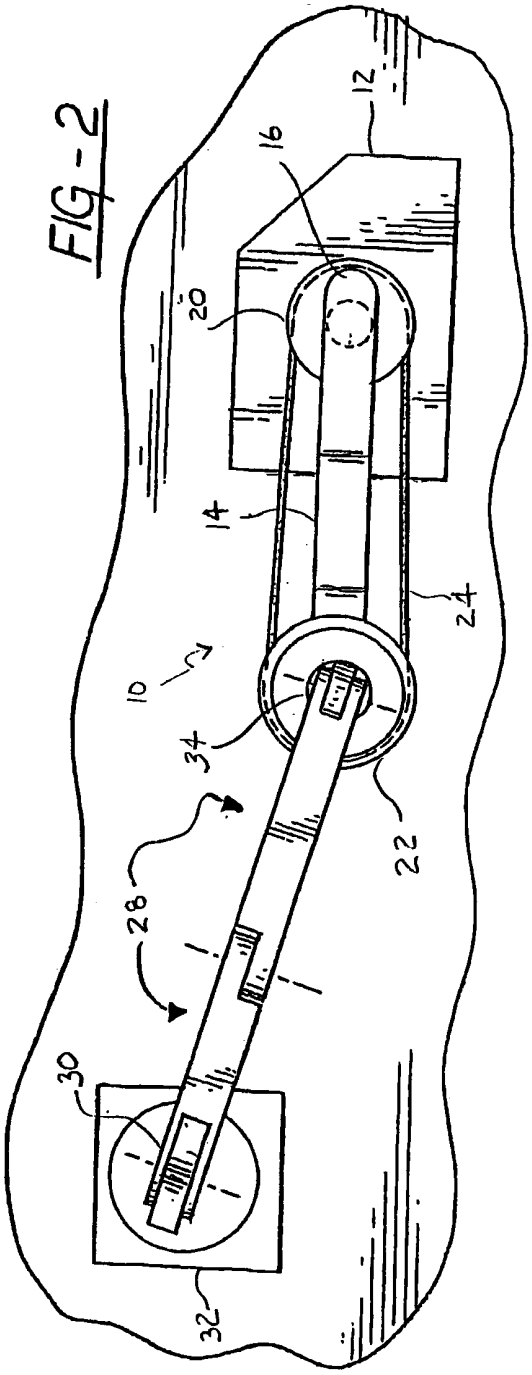
FIG - 2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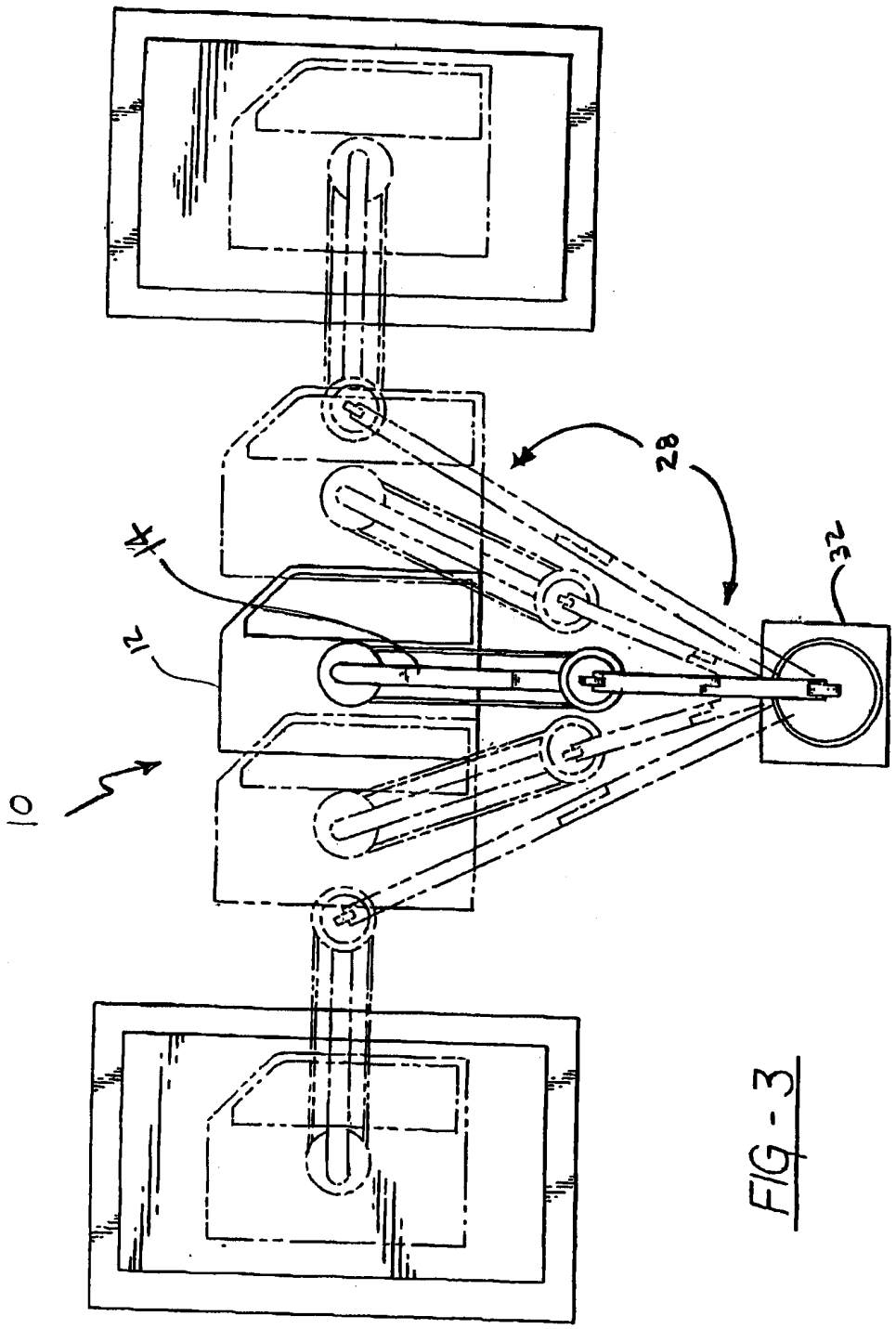


FIG - 3

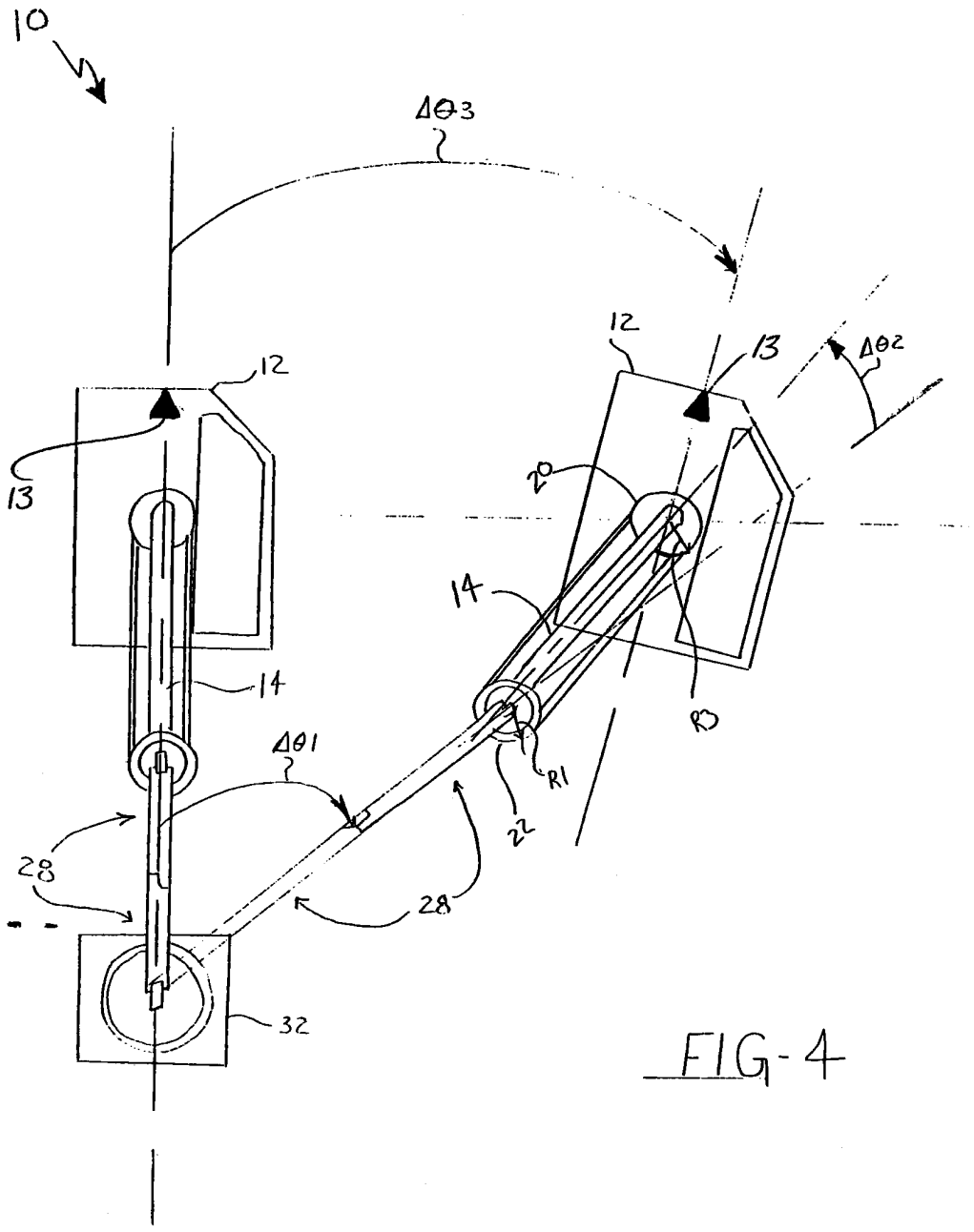


FIG-4

# INTERNATIONAL SEARCH REPORT

Inte ional Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B25J9/04 B25J9/10 B21D43/10 B65G47/90

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B25J B21D B65G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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| | -/-- | |

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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